Introduction to Parallelism & Parallelism on HPC

Examples in Julia and Python

Criston Hyett

December 7, 2022

What is parallelism?

- The common idea of **divide and conquer**
- Works extremely well in many relevant scenarios
  - Large dimension linear algebra, (i.e. ML)
  - Monte Carlo
  - Ordinary/Partial/Stochastic Differential equations (big linear algebra + Monte Carlo)
- Not a panacea!
  - Inefficient code can be inefficient *and* consume plenty of cpu-hours on the HPC

When should you care?

- When the benefits outweigh the costs!
- Costs
  - **Human costs:** Coding, debugging, refactoring
  - **Computational Costs:** parallelism requires coordination between threads, and/or nodes. When this coordination is required often, or significant data is passing between threads, parallel benefits may be outweighed.
- Benefits
  - **Computation speed**
  - **Smaller memory overheads per thread**
  - Process independence

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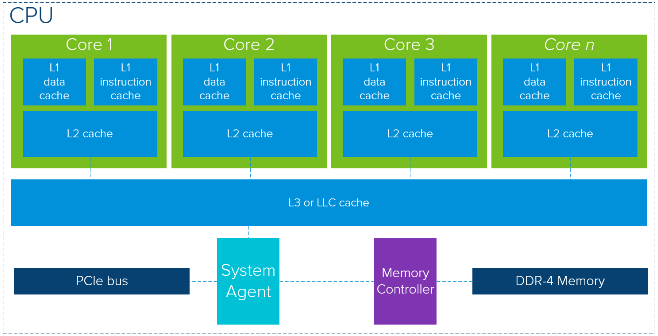
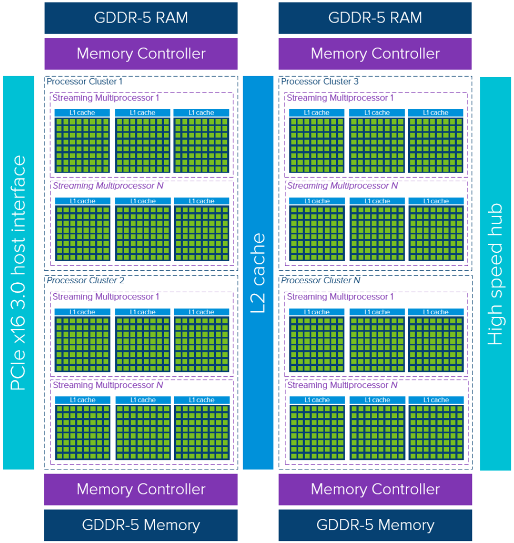
Many of the costs are mitigated by modern languages providing thread-safe, optimized libraries.

Parallel paradigms: CPU



https://core.vmware.com/resource/exploring-gpu-architecture

Parallel paradigms: GPU



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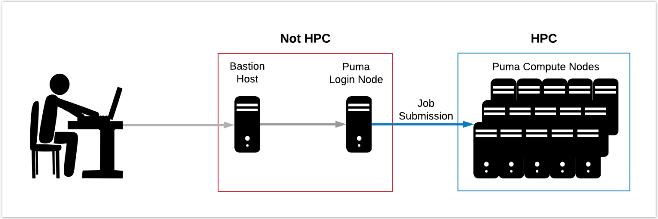
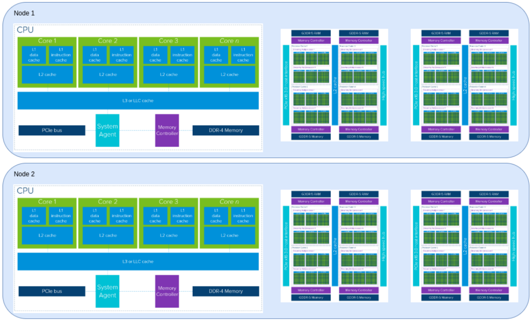
Parallel paradigms: Multi-node





https://public.confluence.arizona.edu/display/UAHPC/Puma+Quick+Start

Word of warning

- Not all code is parallelizable! Improper implementations can lead to
  - Race conditions
  - Deadlock
  - Memory Corruption

```
badParallel.jl

a = 0;
for i in 1:1000
    global a += 1;
end
println("serial a = $(a)");

a = 0;
Threads.@threads for i in 1:1000
    global a += 1;
end
println("parallel a = $(a)");

# serial a = 1000
# parallel a = 881
```

CPU Thread parallelism

Julia: `helloWorld.jl`

```
numThreads = Threads.nthreads();
Threads.@threads for i in 1:numThreads
    println("Hello World!"*
"This is thread # $(Threads.threadid())");
end

# Hello World! This is thread # 1
# Hello World! This is thread # 6
# Hello World! This is thread # 3
# Hello World! This is thread # 4
# Hello World! This is thread # 5
# Hello World! This is thread # 2
```

Python: `helloWorld.py`

```
import threading;
from time import sleep;
import numpy as np;
def helloWorld():
    sleep(np.random.random());
    print("Hello world! This is {}"
          .format(threading.current_threa

if __name__ == "__main__":
    for i in range(6):
        t = threading.Thread(
            target=helloWorld,args=[]);
        t.start()

# Hello world! This is Thread-4
# Hello world! This is Thread-1
# Hello world! This is Thread-6
# Hello world! This is Thread-2
# Hello world! This is Thread-5
# Hello world! This is Thread-3
```

GPU Thread parallelism

- Even easier introduction to Cuda

Node parallelism via Slurm

```
monteCarlo.jl
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basepath = "/home/u1/cmhyett/.julia/dev/LDM/"
using Pkg;
Pkg.activate(basepath);
Pkg.instantiate();
denom = ARGS[1];
outputPath = ARGS[2];
include(basepath * "./src/LDM.jl");
inputPath = basepath * "./results/pi$(denom)/lagrData_pi$(denom).jls"
LDM.TBNN.runTBNN(inputPath,
                 outputPath,
                 maxiters=800,
                 learningRate=1e-3)
```

Node parallelism via Slurm

```
monteCarlo.slurm
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#!/bin/bash

# --------------------------------------------------------------
### PART 1: Requests resources to run your job.
# --------------------------------------------------------------
### Optional. Set the job name
#SBATCH --job-name=test_test
### Optional. Set the output filename.
### SLURM reads %x as the job name and %j as the job ID
#SBATCH --output=%x-%j.out
### REQUIRED. Specify the PI group for this job
###SBATCH --account=chertkov
### Optional. Request email when job begins and ends
### SBATCH --mail-type=ALL
### Optional. Specify email address to use for notification
### SBATCH --mail-user=<YOUR NETID>@email.arizona.edu
### REQUIRED. Set the partition for your job.
#SBATCH --partition=windfall
### REQUIRED. Set the number of cores that will be used for this job.
#SBATCH --ntasks=20
### REQUIRED. Set the number of nodes
#SBATCH --nodes=1
### REQUIRED. Set the memory required for this job.
#SBATCH --mem=64gb
### REQUIRED. Specify the time required for this job, hhh:mm:ss
#SBATCH --time=02:00:00

#SBATCH --array=1-20

# --------------------------------------------------------------
### PART 2: Executes bash commands to run your job
# --------------------------------------------------------------
### Load required modules/libraries if needed
module load python/3.8
module load julia/1.7.2
### change to your script's directory
cd /home/u1/cmhyett/.julia/dev/LDM/results/pi512/
julia ../tbnnFamilyTrainScript.jl 512 /xdisk/chertkov/cmhyett/tbnnFamilyTraining/pi512/latent_space/task_${SLURM_ARRAY_TASK_ID}/
```

References & Further Reading

- https://core.vmware.com/resource/exploring-gpu-architecture
- https://public.confluence.arizona.edu/display/UAHPC/Puma+Quick+Start
- https://www.tensorflow.org/guide/gpu
- https://developer.nvidia.com/blog/even-easier-introduction-cuda/
- https://public.confluence.arizona.edu/display/UAHPC/Using+and+Installing+Python